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PLANAR SYMMETRY FLUCTUATIONS IN ELECTROMAGNETIC SHOWERS INDUCED IN LIQUID XENON BY PHOTONS BETWEEN 100 AND 3500 MeV

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Planar symmetry of electromagnetic showers created by gamma quanta of energy E_γ = 100—3500 MeV has been studied using pictures of the 180 liter xenon bubble chamber of ITEP (Moscow). We have measured the energy dependence of a shift, from the shower axis, of the plane dividing a shower into halves and found that the average value of this shift decreases roughly linearly with ln E_γ increasing. The energy behaviour of the relevant r.m.s. as well as the shower symmetry depth and its r.m.s. is also obtained.

The investigation has been performed at the Laboratory of High Energies, JINR (Dubna) and at the Institute of Physics of the Warsaw University of Technology.

Флуктуации зеркальной симметрии в электронно-фотонных ливнях, вызванных гамма-квантами с энергией от 100 до 3500 МэВ в жидком ксеноне

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Изучена зеркальная симметрия в электронно-фотонных ливнях, создаваемых гамма-квантами с энергией E_γ = 100—3500 МэВ. В качестве экспериментального материала использованы снимки 180 л ксеноновой пузырьковой камеры ИТЭФ (Москва), облученной в пучке π^--мезонов с импульсом 3,5 ГэВ/с. Измерена энергетическая зависимость сдвига, относительно оси ливня, плоскости, разделяющей ливень на две половины, и установлено, что средняя величина этого сдвига уменьшается приблизительно линейно с ростом ln E_γ. Получена зависимость от энергии соответствующего среднеквадратичного отклонения (с.к.о.), а также глубины симметрии ливня и ее с.к.о.

Работа выполнена в Лаборатории высоких энергий ОИЯИ (Дубна) и в Институте физики Варшавского технического университета.

I. Introduction

Precise measurement of the position of high energy gamma quanta registered by a hodoscope gamma spectrometer (for example, [1]) requires a good knowledge of axial symmetry fluctuations in electromagnetic showers created by these gammas. It is evident that such fluctuations increase the errors of estimation of effective masses of gammas accompanying hadronic interactions at high energies and set a natural limit to the accuracy of measurements. Unfortunately, the problem of axial (or lateral) symmetry distortion in showers has not been raised until very recently in literature[2] and, in particular, was not yet touched on experimentally at all. As a consequence, every single event of a shower registered in the hodoscope is actually considered to be axial symmetric as it is indeed the case in homogenous media but on the average only.

In this article we present the results of investigation of planar symmetry distortion in electromagnetic showers produced by photons between 100 MeV and 3500 MeV in liquid xenon. For this purpose our previous data obtained from the pictures of the 180 liter xenon bubble chamber of ITEP (Moscow)[3] exposed to the beam of π^- mesons at 3.5 GeV have been used.

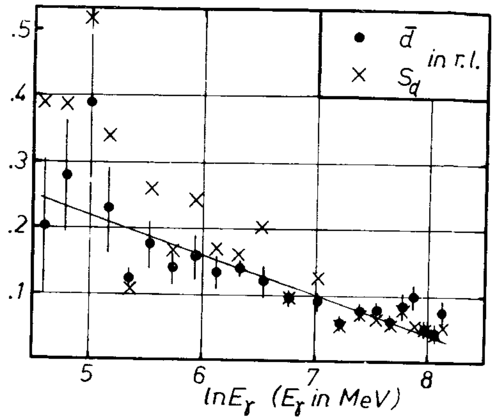
II. Material and Method

The experimental material consists of 908 events of showers satisfying the appropriate criteria and grouped into 22 intervals of primary photon energy E_γ in such a way that the relative width $\Delta E_\gamma / E_\gamma$ of each interval is not less than the average energy resolution ($\cong$0.1). In all cases of these events summary projection ranges of shower electrons and positrons (later: electrons) of energy greater than 0.5—1.5 MeV observed in the projection plane (PP) within a rectangle of side $\Delta t = 0.6$ radiation length (r.l.) along the shower axis (SA) and $\Delta p = 0.3$ r.l. in its laretal direction, have been measured with an average accuracy of 0.2. The shower electron ranges, both summed over the whole shower event and some their part contained inside a rectangle of large enough area in the PP, are practically proportional to ionization losses released by these electrons with an accuracy of ~2—3%[4,5]. In more detail methodical problems are described in[6].

III. Planar Symmetry Fluctuation

Figure 1 shows the energy distribution of such average distance $\bar{d}$ from the SA in the PP that a plane perpendicular to the PP and a distance d from SA divides a given shower event into two equal parts having, on the average, the same values of summary electron

Fig.1. Average shift $\bar{d}$ of a shower symmetry plane from the shower axis and the relevant r.m.s. S_d. Superimposed is the fitting function for $\bar{d}$ (1)



ranges. The distribution of estimates of r.m.s. S_d is also plotted in the figure. As to be expected, both $\bar{d}$ and S_d decrease with increasing energy E_γ, and at $E_\gamma >> 1000$ MeV these quantities become less than ~0.1 r.l. The simple fitting function for $\bar{d}$

$$\bar{d} = (0.52\pm0.03) - (0.059\pm 0.004)\cdot\ln E_\gamma \qquad (1)$$

is also displayed on this figure as a straight line. Here E_γ is in MeV; $\bar{d}$, in r.l. and the relevant linear correlation index equals $r = 0.83$.

IV. Symmetry Depth, Its Fluctuation and Correlation

From practical point of view it seems important to know at what value of the shower depth t_s, being the most remote from the conversion point of a primary photon and measured along the SA, a shower may be considered to be planar symmetric with respect to a plane passing the SA. The distribution of $\bar{t}_s$ averaged over all fluctuations is shown in fig.2 as a function of E_γ together with the distribution of the relative r.m.s. S_{t_s}. One can

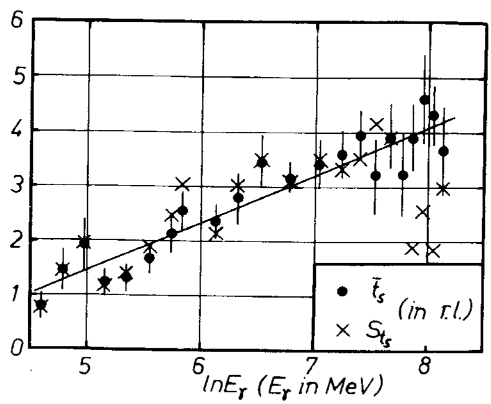


Fig.2. Average maximum depth $\bar{t}_s$ at which the showers remained planar symmetric with a symmetry plane passing the shower axis. S_{t_s} is the corresponding r.m.s. The straight line represents the fitting function for $\bar{t}_s$ (2)

notice from the figure that $\bar{t}_s$ and S_{t_s} increase approximately linearly with $\ln E_\gamma$. For $\bar{t}_s$ one can admit

$$\bar{t}_s = -(2.9\pm0.4) + (0.87\pm 0.07)\cdot\ln E_\gamma$$

at $r = 0.94$, E_γ is in MeV; $\bar{t}_s$, in r.l. This function is superimposed in the figure as a straight line.

Finally, the correlation between the symmetry depth and the shift d has been studied and found that the appropriate correlation coefficient does not exeed 0.5 within all interval of energy considered. So, one can infer that no such a correlation perceptible occurs.

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